UNCLASSIFIED

UNCLASSIFIED

(1)

AD No. 461360
DDC FILE COPY

4 6 1 3 6 0

TECHNICAL MEMORANDUM

U.S. NAVAL APPLIED SCIENCE LABORATORY
NAVAL BASE
BROOKLYN, NEW YORK 11251

DDC
RECEIVED
APR 23 1965
DDC-IRA E

21160

USNASL-9110-P-1J(REV. 10-64)

Sept 27601

(upper case)

6 Fatigue of Iron Base Alloys HY-80 Steel
Cast Tees Butt Welded to Rolled Section
Single and Double Weld Joint Design.

[redacted]

17

SR 007-01-01 Task 0856

11 14 Dec [redacted]64

9 Technical memo.

14 Rept. nos. 9300-1; TM-19

~~Material Sciences~~ Division

Approved [signature]
[redacted]
Associate Technical Director

5

[redacted], NAVAL APPLIED SCIENCE LAB[redacted] .,
[redacted], BROOKLYN, N[redacted] Y[redacted]

58061 **FATIGUE OF IRON BASE ALLOYS HY-80 STEEL CAST TEES BUTT WELDED TO ROLLED SECTION SINGLE AND DOUBLE WELD JOINT DESIGN.** United States Naval Applied Science Laboratory, Naval Base, Brooklyn, New York. Technical Memorandum 19, December 14, 1964
(6 pages, 6 figures, 2 tables)

70
F
27601

This memorandum presents a summary of results of fatigue tests of HY-80 steel, cast tees butt welded to rolled plate.

Battelle DMIC
Jan 1965

TABLE OF CONTENTS

Lab. Project 9300-1
Technical Memorandum 19

ADMINISTRATIVE INFORMATION

Ref: (a) NAVAPLSCIENLAB Program Summary of 1 May 1964 SR007-01-01-Fabrication of High Strength Steel Alloys
(b) BUSHIPS ltr R007-01-01 Ser 634B-634 of 22 Aug 1963
(c) BUSHIPS ltr R007-01-01 Ser 634B-18 of 9 Jan 1964
(d) NAVAPLSCIENLAB Project 9300-1, Progress Report 1 of 15 Apr 1964
(e) NAVAPLSCIENLAB Project 9300-1, Technical Memorandum 11 of 8 Jul 1964
(f) NAVAPLSCIENLAB Project 9300-1, Technical Memorandum 15 of 25 Aug 1964
(g) NAVAPLSCIENLAB Project 9300-1, Technical Memorandum 18 of 30 Sep 1964
(h) NAVSHIPYDNYK MAT LAB Project 6160, Progress Report 7 of 28 Jun 1963
(i) NAVAPLSCIENLAB Project 6160-2, of 16 Sep 1963
(j) NAVSHIPYDNYK MAT LAB Project 6160-2 Progress Report 3 of 17 Jul 1961

1. In connection with its high strength steel program outlined in reference (a), the U. S. Naval Applied Science Laboratory is investigating the fatigue properties of HY-80 welds and methods for their improvement along the lines included in references (b) and (c). The results of these tests on NASL plate type tee fillet welded specimens were previously reported as follows: "as welded" condition and mechanically peened, reference (d); ground, reference(e), shot peened,reference (f), and ground and shot peened, reference (g). Comparison of results on cast tees with those on tee fillet welds was reported under reference (h). Results of fatigue properties of rolled plate butt welded to cast plate was reported under reference (i). This memerandum presents a summary of results of fatigue tests of HY-80 steel, cast tees butt welded to rolled plate.

OBJECTIVE

2. The objectives of the work, covered by this memorandum were to:

a. Determine the fatigue life of HY-80 steel cast tees butt welded to rolled sections and,

b. Compare the effectiveness of single and double vee weld joint designs.

DESCRIPTION

3. Four NASL plate type specimens as shown on Figure 1 were used in the fatigue tests. The cast tee material of the four plates used in this phase of the program is the same as that reported in reference (h). The rolled section of the specimen was obtained from the L5 HY-80 plate. Data relative to the identification, chemical analyses and mechanical properties of all plates are shown on Table 1. The specimens were designed to be simply supported along the 32 inch length at a

span of 28 inches, free along the two short edges, and uniformly loaded over the entire surface. Two specimens (Code 17 CR) were butt welded with a single vee weld joint design and two specimens (Code 31 CR) with a double vee.

4. Details of the typical welding procedure, joint design and pass sequence are shown in Figure 1A.

5. The specimens were tested in the NASL Plate Fatigue Machine, described in detail in reference (j). The machine supports the plates and permits repeated application of uniform pressure on the lower face. Two dial indicators are mounted on the machine to measure deflections along the centerline of the specimen. A deflection recorder is also mounted on the frame to provide a continuous record of deflection throughout the test.

METHOD

6. Each of the four specimens were subjected to pulsating uniform loading varying from zero to a maximum in flexure at a rate of 12 cycles per minute in the Fatigue Machine. One pair of specimens consisting of one plate with single vee and one plate with double vee butt weld joint design was run at a nominal outer-fiber stress of 80,000 psi at the toe of the weld and the other pair at 90,000 psi, calculated by means of the simple beam formula. A continuous indication of deflection was recorded throughout the test and the test was stopped at ultimate failure which was considered to have occurred when the deflection under the maximum load increased 100 percent over the initial deflection at the start of the fatigue run. During the course of the test, minimum and maximum dial indicator readings were recorded at intervals of 500 loading cycles. In addition, observations were made to determine the approximate number of cycles at which a crack started and progressed to various lengths. Prior to testing, SR-4 type strain gages were cemented along the toe of the weld and approximately one inch from the toe of the weld to provide a measure of tensile strains. These measurements were taken during static loading of the specimens prior to the start of fatigue testing.

RESULTS & DISCUSSION

7. The results of fatigue tests on the large scale specimens of cast tee butt welded to rolled plate are given in Table 2. The number of cycles to first appearance of a crack, to 10 percent increase in deflection and to 100 percent increase in deflection are also tabulated. Values based on 10 percent increase in deflection over the initial deflection are shown plotted on S-N coordinates in Figure 2. Similar data obtained on cast tees, base plate, butt welds and cast plates butt welded to rolled plates, previously reported in reference (i) are also plotted on Figure 2 for comparison. No attempt has been made to draw a curve through the test points for the cast tee butt welded to rolled plate because of the

limited data. It is evident, however, that the fatigue life of these plates is about the same as that of one inch thick rolled plate butt welds and 1 5/8 in. thick cast plate-to-rolled-plate butt welds, and significantly lower than that of the base plate and cast tees at corresponding stress levels. As may be observed from Figure 2, that for the cast tee to rolled plate butt welds, the fatigue life of the single vee design is greater than the double vee design at 90,000 psi and lower at 80,000 psi. However, these differences may not be considered significant because they represent normal scatter of fatigue data.

8. Typical deflection records obtained during the fatigue runs on HY-80 cast tee to rolled plate butt welds as cracks propagated through the critical section are shown in Figures 3 and 4. The sharp rise in deflection when the number of cycles approached the limit of ultimate failure is noted for all of the curves in the figure.

9. The progress of cracks along the welds in each specimen is illustrated on Figures 5 and 6. Five conditions, each identified by the number of cycles, are shown for each specimen. First indications of crack formation are designated by crosses and continuous cracks by heavy solid lines. The lengths of cracks are drawn to scale. No attempt has been made to indicate the depth of the crack on these sketches. The results indicate that fatigue cracks appear early in the life of the cast tee butt welded to rolled plates at random locations along the weld. Repeated loading causes the cracks to form and extend along the length of the weld, ultimately to join and penetrate down into the base plate. The cracks had tranversed almost the full length of the weld at ultimate failure. There appears to be no significant difference in the manner in which the cracks propagate along the length of the weld on the cast or the rolled side of the plate.

CONCLUSIONS

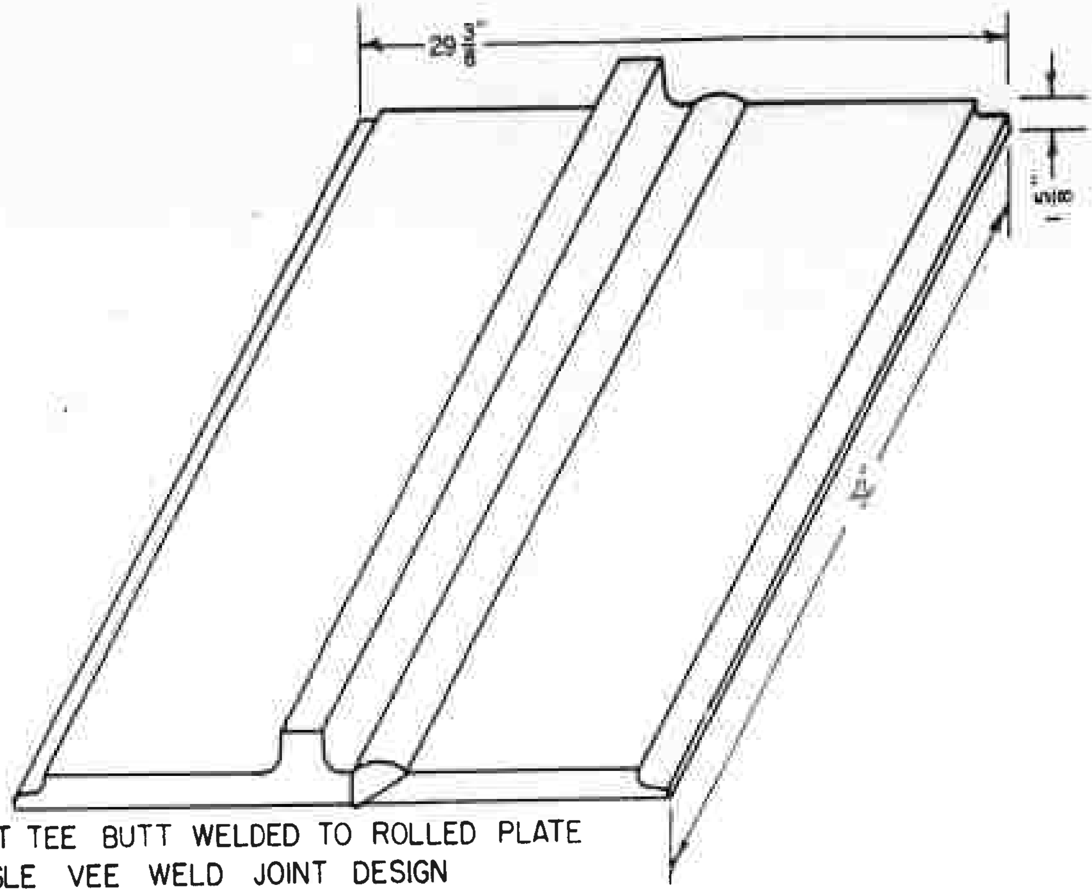
10. The average fatigue life of 1 5/8 in. thick cast tee butt welded to rolled plate is approximately the same as that of cast plate butt welded to rolled plate and rolled plate butt welded to rolled plate.

11. At 80,000 psi nominal stress range the fatigue life of these butt welds is approximately 20,000 cycles.

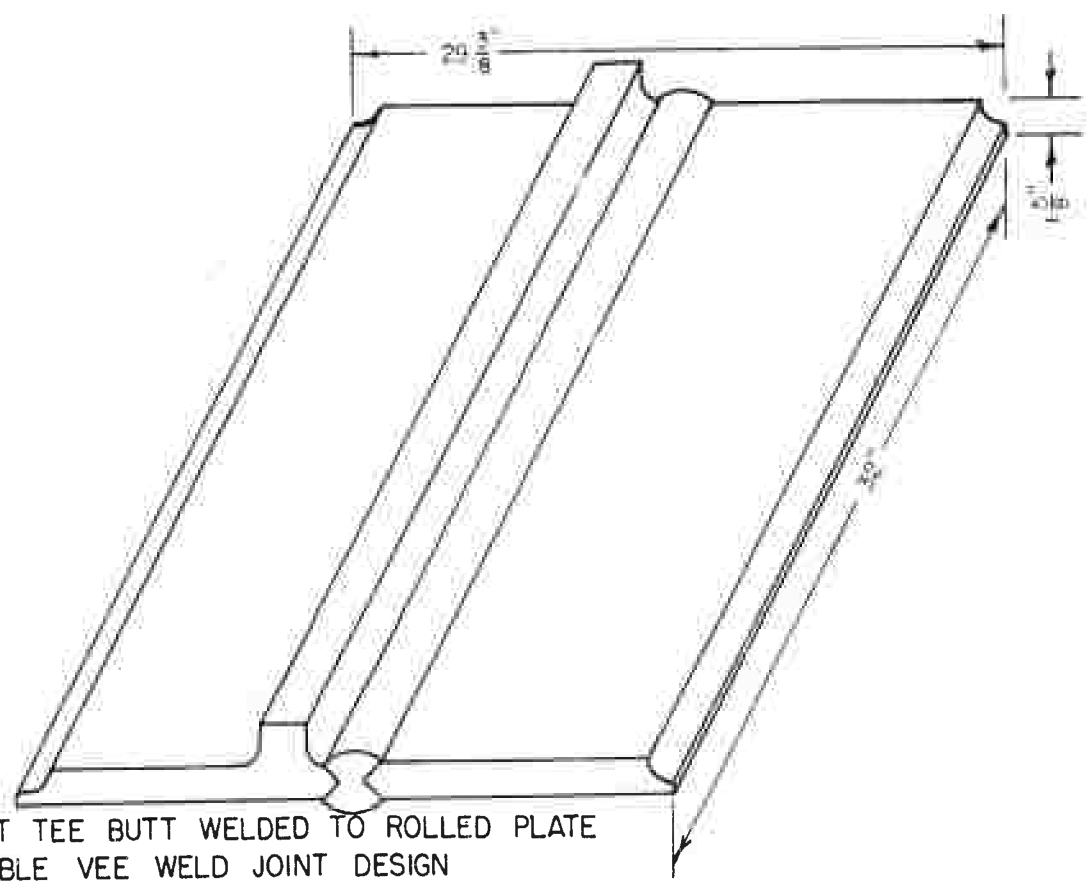
12. No significant difference in the fatigue life of single and double vee butt joints can be estimated because the differences in fatigue life represent normal scatter of fatigue data, and because the amount of data is limited.

FUTURE WORK

13. Work is now in progress on as-welded and mechanically-peened HY-80 butt welded plate type fatigue specimens. Results of these tests will be reported in approximately two months.



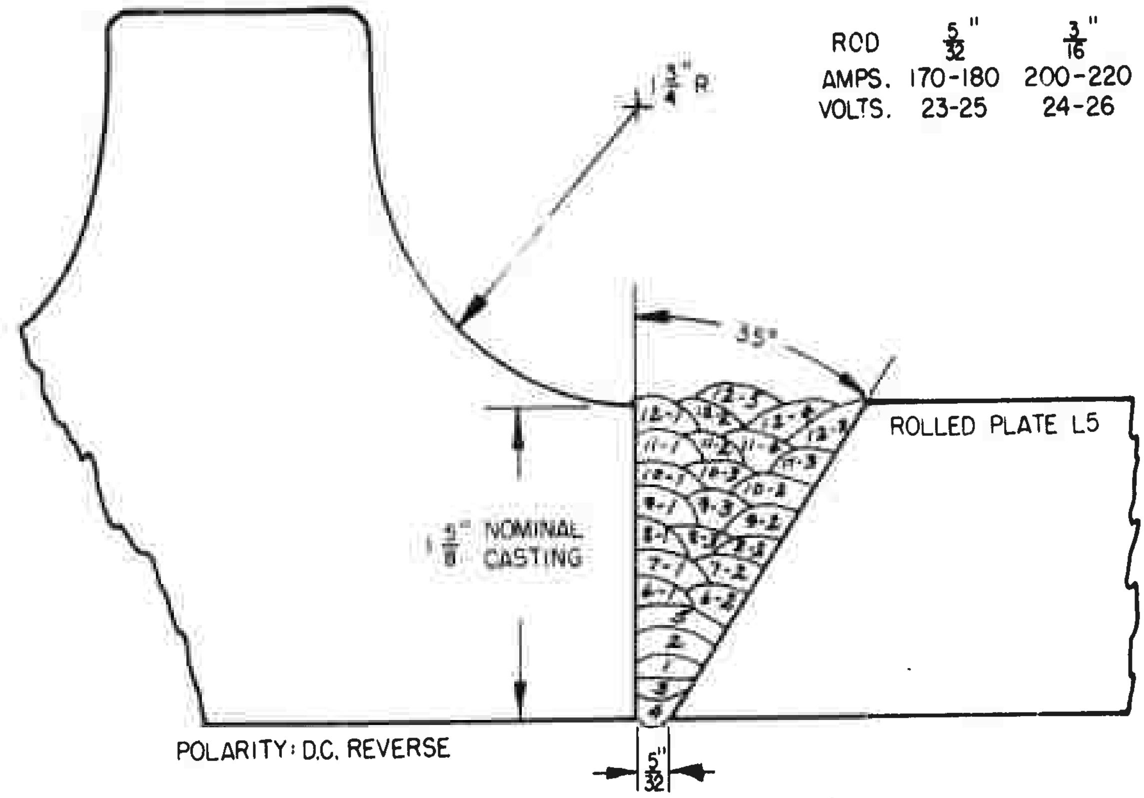
CAST TEE BUTT WELDED TO ROLLED PLATE
SINGLE VEE WELD JOINT DESIGN



CAST TEE BUTT WELDED TO ROLLED PLATE
DOUBLE VEE WELD JOINT DESIGN

FIGURE 1 – PLATE TYPE FATIGUE SPECIMEN

ROD	5/32"	3/16"
AMPS.	170-180	200-220
VOLTS.	23-25	24-26



POLARITY: D.C. REVERSE

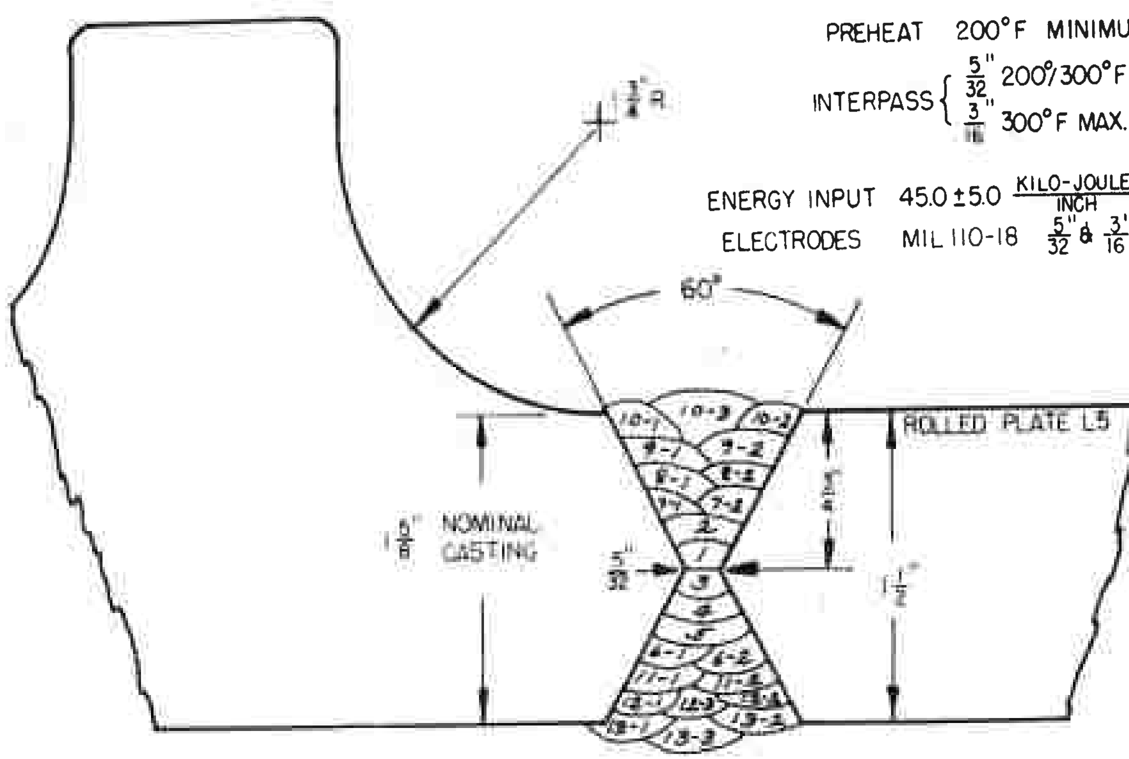
SINGLE BEVEL CODES 17CR(3,4)

PREHEAT 200°F MINIMUM

INTERPASS { 5/32" 200°/300°F; 3/16" 300°F MAX.

ENERGY INPUT 45.0 ± 5.0 KILO-JOULES/INCH

ELECTRODES MIL 110-18 5/32" & 3/16"



DOUBLE BEVEL CODES 31CR(1,2)

FIGURE 1A - JOINT DESIGN

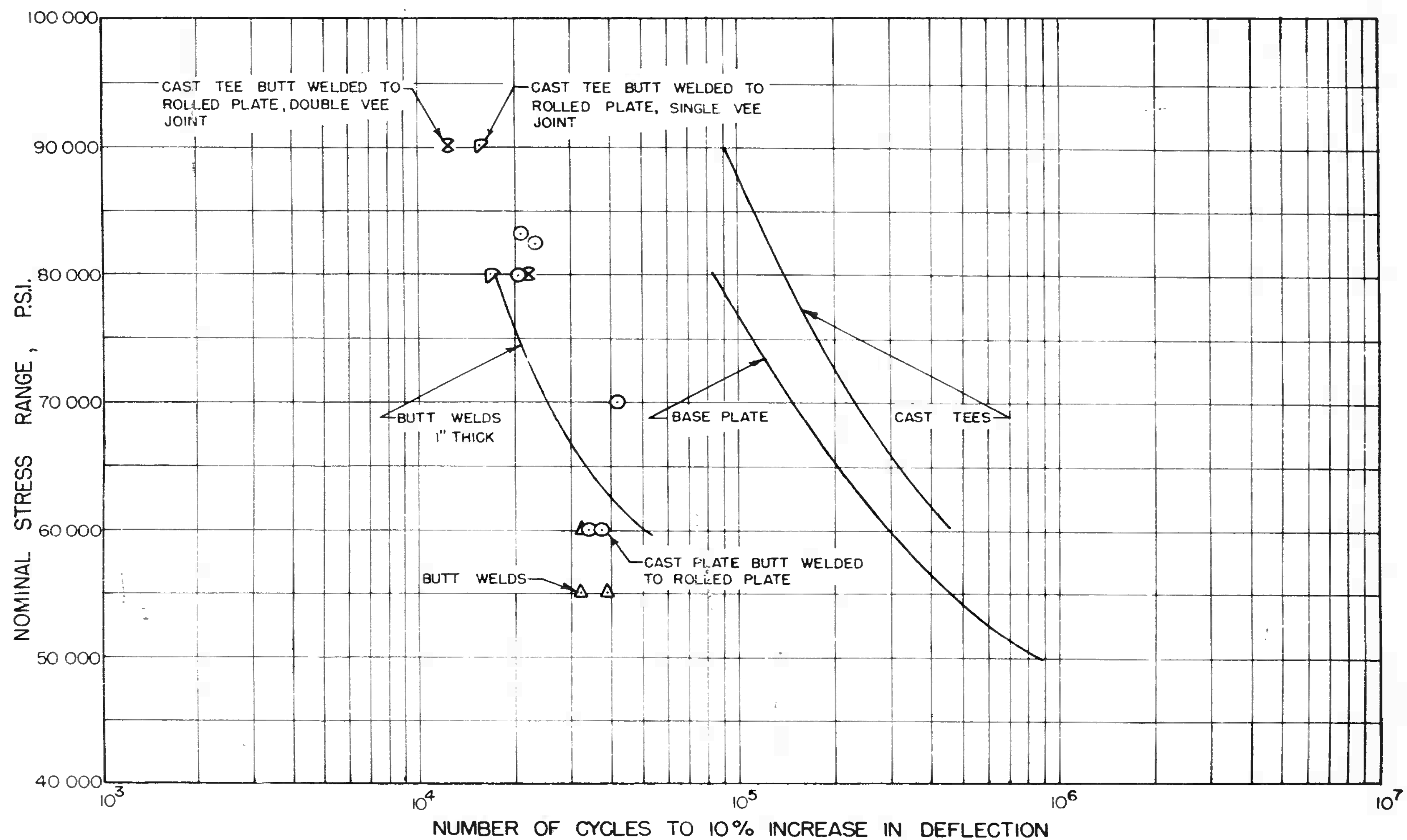


FIGURE 2 - COMPARISON OF FATIGUE RESULTS OBTAINED ON VARIOUS HY-80 1-5/8 INCH THICK PLATE TYPE SPECIMENS

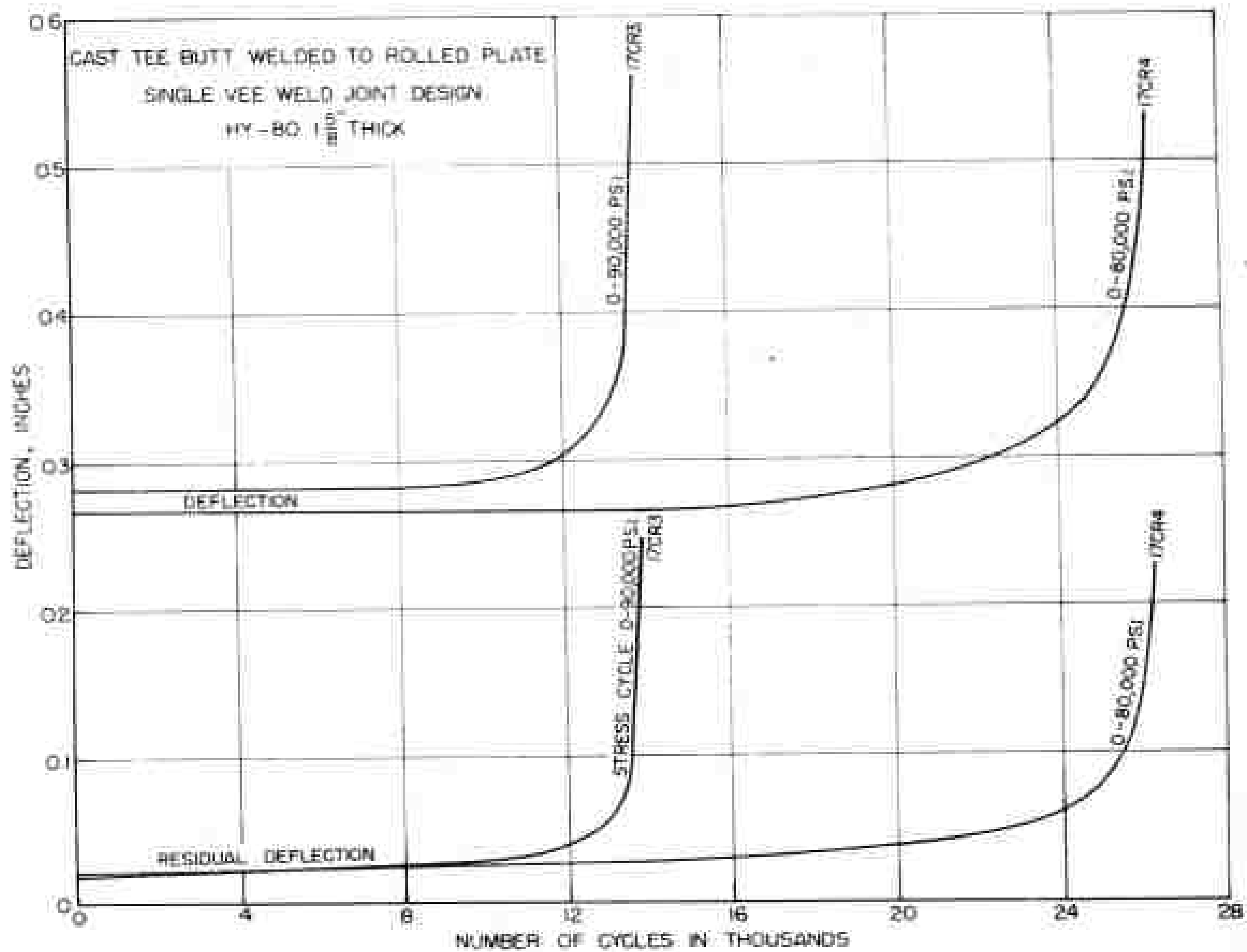


FIGURE 3 - CURVES SHOWING PROGRESSIVE INCREASE IN DEFLECTION AS CRACK PROPAGATED THROUGH THE CRITICAL SECTION OF PLATE TYPE SPECIMENS AT INDICATED NOMINAL STRESSES

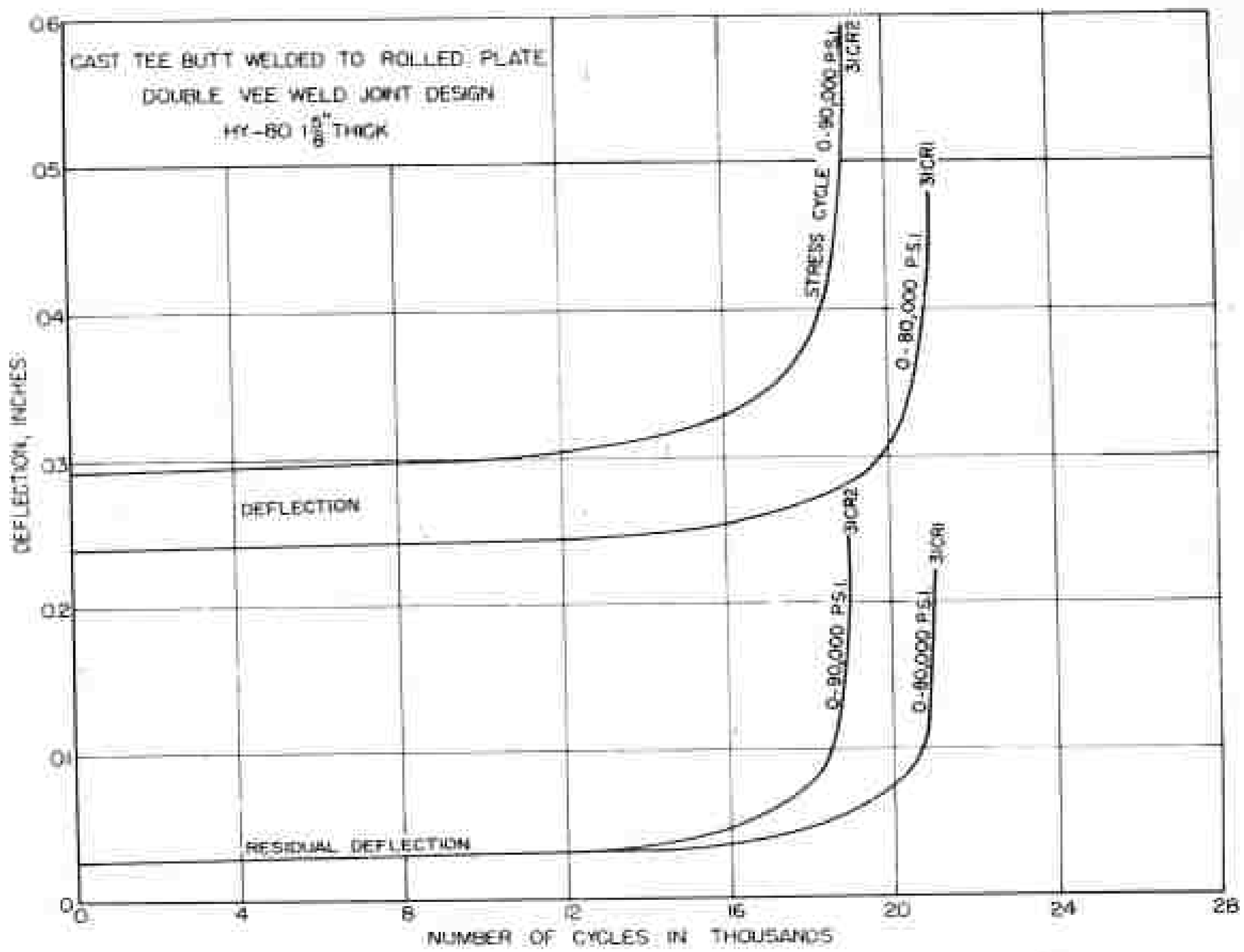


FIGURE 4 - CURVES SHOWING PROGRESSIVE INCREASE IN DEFLECTION AS CRACK PROPAGATED THROUGH THE CRITICAL SECTION OF PLATE TYPE SPECIMENS AT INDICATED NOMINAL STRESSES

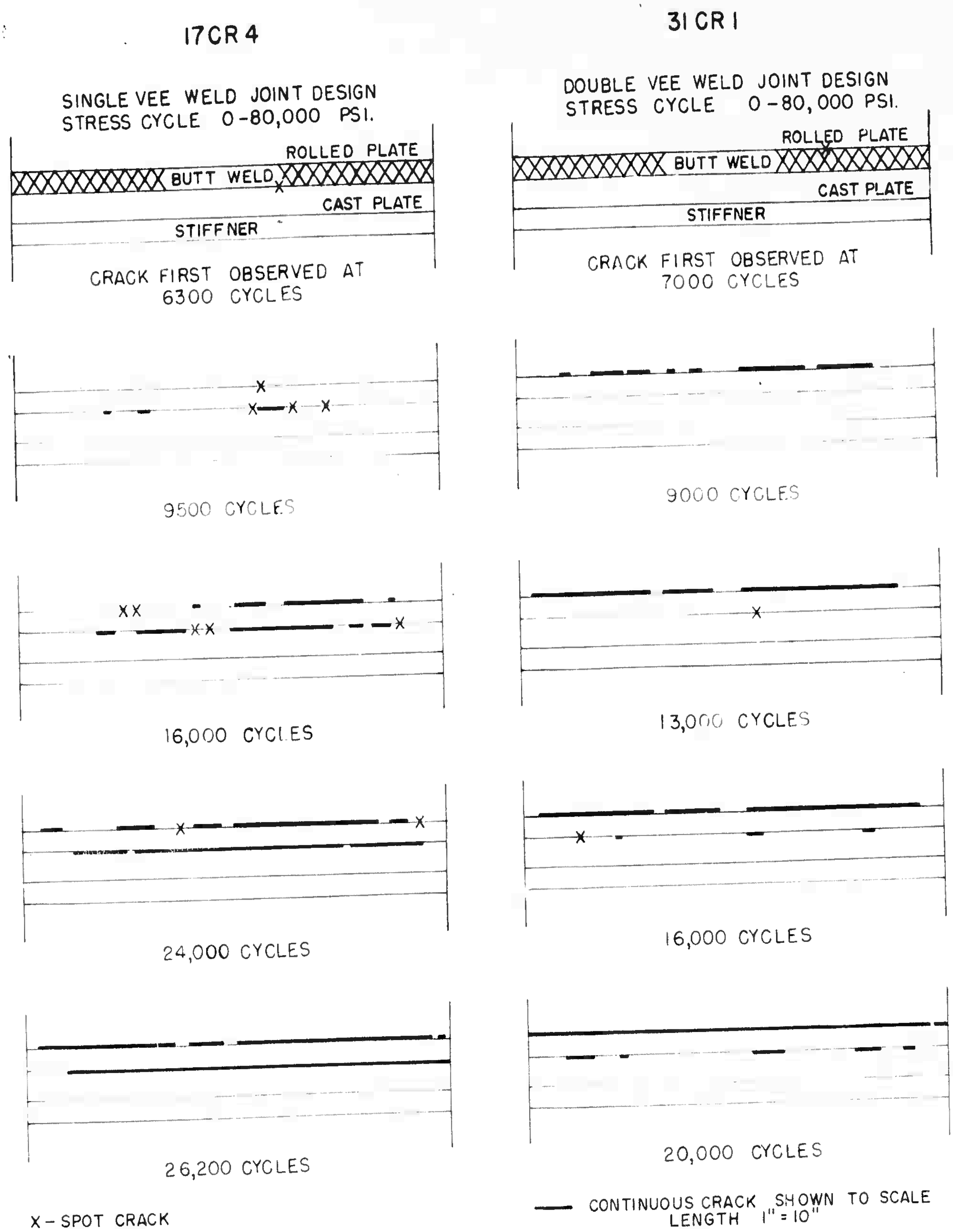


FIGURE 5- CRACK PROGRESS IN CAST TEE BUTT WELDED TO ROLLED PLATE

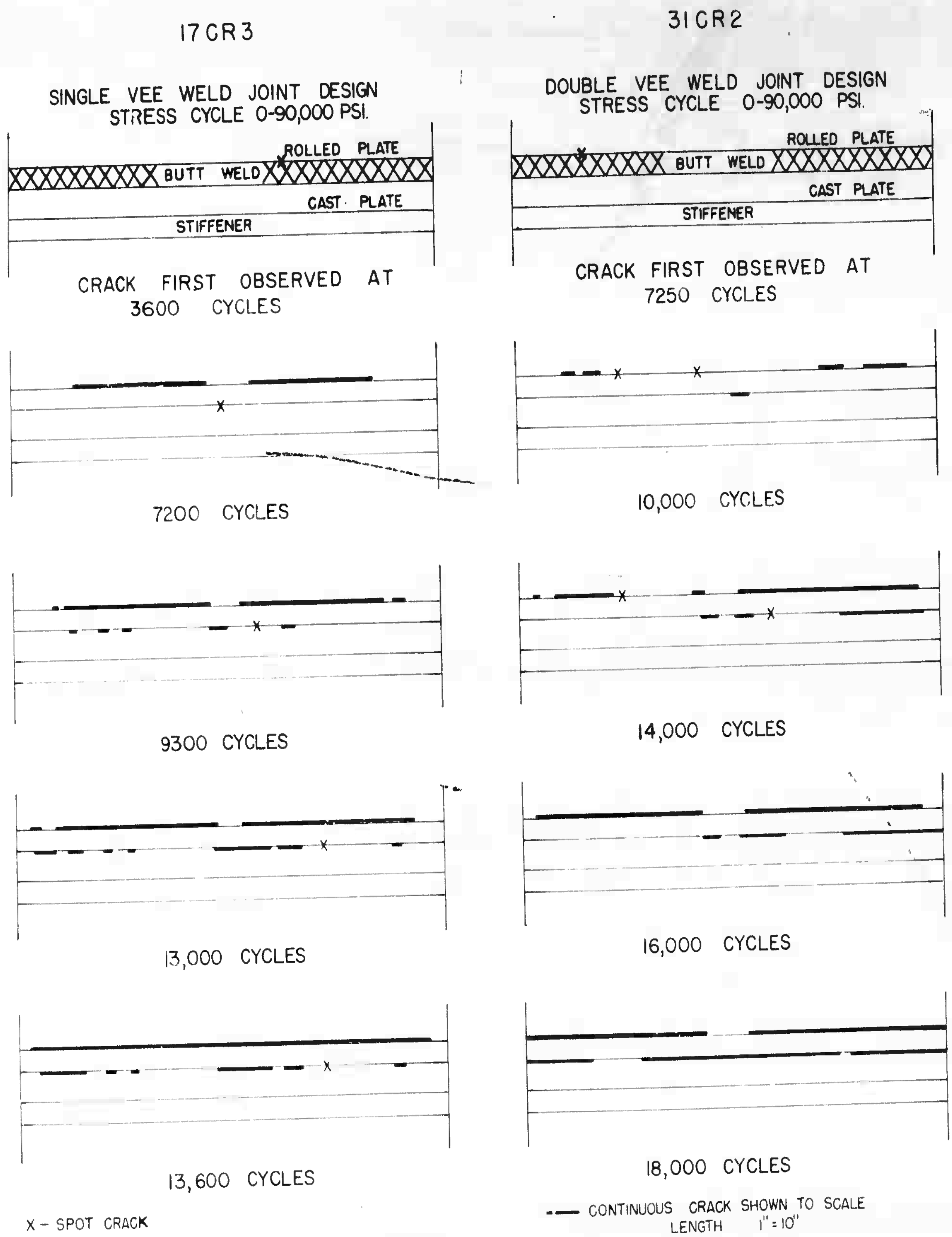


FIGURE 6 - CRACK PROGRESS IN CAST TEE BUTT WELDED TO ROLLED PLATE

Table 1

Chemical Analyses and Mechanical Properties of HY-80

Cast Tees and Rolled Plate

Chemical Analysis (%)	Cast Plate	Specification MIL-S-23008A	Rolled Plate	Specification MIL-S-16216
C	0.16-0.19	0.20 (Max)	0.17	0.18 (Max)
Mn	0.57-0.60	0.55-0.75	0.28	0.10-0.40
P	0.009-0.012	0.020 (Max)	0.010	0.025 (Max)
S	0.010-0.012	0.015 (Max)	0.019	0.025 (Max)
Si	0.38-0.51	0.50 (Max)	0.24	0.15-0.35
Ni	2.80-2.95	2.50-3.25	2.94	2.00-2.25
Cr	1.42-1.65	1.35-1.65	1.47	1.00-1.80
Ti	--	0.02(Max)	--	0.02 (Max)
Cu	--	0.20(Max)	--	0.25 (Max)
Mo	0.46-0.48	0.30-0.60	0.43	0.20-0.60
V	--	0.03 (Max)	--	0.03 (Max)
Yield Strength (ksi) 0.2% Offset	87.0-91.0	80.0-95.0	83.2(L) 87.2(T)	80.0-95.0
Tensile Strength (ksi)	--	--	104.6(L) 102.6(T)	--
Elongation % in 2 inches	23.0-25.0	20.0	29.0(L) 26.0(T)	20.0
Reduction in Area %	--	--	74.64(L) 68.91(T)	55.0(L) 50.0(T)
Charpy V-Notch Average (ft-lbs)	59.0-65.0	At-100°F 30	123.0(L) 84.0(T)	At-120°F 50

(L) Longitudinal (Parallel to Direction of Final Roll) Tensile Specimen
(T) Transverse (Perpendicular to Direction of Final Roll) Tensile Specimen

TABLE 2

SUMMARY OF RESULTS OF FATIGUE TESTS ON CAST TEES BUTT WELDED TO ROLLED PLATES - SINGLE AND DOUBLE VEE WELD JOINT DESIGN

Specimen No.	Type of Weld	Calculated Nominal Cyclic Stress (psi)		Average Thickness (Inches)		Applied Pressure (psi.)	Initial Deflection (in.)	NUMBER OF CYCLES			
		Cast Side	Rolled Side	Cast Side	Rolled Side			To First Observation of Crack	To 10% Increase in Deflection	To Ultimate Failure	Location of Initial Crack
17CR1	Single Vee	75,100	80,000	1.538	1.482	302	0.268	6300	22,100	26,210	On Cast Side 12" from End C
31CR1	Double Vee	64,200	80,000	1.670	1.492	304	0.238	7000	16,800	21,050	On Rolled Side 8" from End C
17CR3	Single Vee	77,950	90,000	1.609	1.480	341	0.279	3600	12,250	13,800	On Rolled Side 10" from End C
31CR2	Double Vee	83,460	90,000	1.539	1.483	339	0.292	7250	15,500	19,000	On Rolled Side 5" from End A